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GROWTH OF SHINER PERCH (CYMATOGASTER AGGREGATA) AND BUFFALO SCULPIN (ENOPHRYS BISON) UNDER LABORATORY CONDITIONS

Anne Hutchison Myers

Pacific Northwest Environmental Research Laboratory

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GROWTH OF SHINER PERCH (*CYMATOGASTER AGGREGATA*) AND BUFFALO SCULPIN (*ENOPHRYS BISON*) UNDER LABORATORY CONDITIONS

By

Anne Hutchison Myers
Western Interstate Council for Higher Education Intern
National Coastal Pollution Research Program
U. S. Environmental Protection Agency
Marine Science Center
Newport, Oregon 97305

SEPTEMBER 1973

Committee Members:

R. C. Swartz
D. T. Martin
W. A. DeBen
D. J. Baumgartner

II

ABSTRACT

Growth rate experiments were carried out for two fish, Enophrys bison and Cymatogaster aggregata, under separate feeding conditions to determine the feasibility of using either for pollutant stress experiments. Enophrys bison would not feed on the three prey species presented. Two month old Cymatogaster aggregata fed Oregon pellets showed an increase in growth rate of 10 mg per gram of body weight per day (dry weight) for each increase in consumption rate of 20 mg per gram of body weight per day (dry weight). A feeding schedule of 0.12 gm (wet weight) of Oregon pellets per day caused a significant weight gain in one week. Feeding 0.06 gm per day caused no significant weight change. Lengths were not significantly different.

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INTRODUCTION

Water pollution standards are often based on acute toxicity bioassays. "Safe" concentrations are estimated by reducing median survival concentration by one or two orders of magnitude. Such limits may not reflect the water quality required for growth, development, reproduction, behavior or even long-term survival. In order to provide a more reliable basis for predicting the fate and effects of pollutants in the oceans, EPA's National Coastal Pollution Research Program has initiated a study of the behavior of experimental marine ecosystems exposed to stress.

I have examined techiques for documenting energy flow through biological systems under normal environmental conditions. This report discusses two experimental approaches: (1) a predator--prey system involving buffalo sculpin (Enophyrs bison) as the predator and two decapod crustaceans and shiner perch as prey; and (2) growth in a single species population of shiner perch (Cymatogaster aggregata) fed an artificial diet. The ultimate application of the results lies in future experiments comparing the flow of energy under normal and stressed conditions.

METHODS

TANK SYSTEM

A flow-through seawater system was established at the Marine Science Center of Oregon State University in Newport, Oregon. Two 575 gallon circular tanks were connected via separate filters to the main seawater supply. The seawater at the Center is pumped from Yaquina Bay through a sand filter. During the period of this experiment salinity was 34 ± 1 percent and the temperature was 12 ± 2°C.

The tanks were zinc-coated iron painted with two coats of Valspar 2802 L.S.C. Primer. Tank A received two coats of Valspar 3825 Nile Green and one coat of Valspar 3836 Dolphin Blue. Tank B had two coats of 3836 Dolphin Blue. All fittings and pipes were PVC. The flow system is diagrammed in Figure 1. A drain cover was placed on the outflow pipe to prevent loss of animals from the system. The flow rate was 2-3 gallons/minute. Both filters were back-washed daily except weekends.

The filters consisted of one foot thick layers of activated carbon, small grain sand (F<1m), large grain sand (<2mm) and crushed oyster shells. The bottom and sides of the tanks were cleaned twice a week.

A third smaller tank was used to keep a small number of fish under observation. This was a rectangular tank of 12 gallon capacity with a flow rate of 1/4 - 1/2 gal/minute. It was connected to Tank A's filter system.

EXPERIMENT 1: PREDATOR-PREY RELATIONS

Buffalo sculpin were collected with an otter trawl during the end of June and the beginning of July, 1973. All the fish were weighed and a few individuals were tagged with Peterson disks and lengths taken. Eleven fish were placed in each of the two large tanks and three food choices were offered for periods of at least one week. Hemigrapsus nudus, a small black shore crab, was collected at Yaquina Head. Crago nigricauda, a small bay shrimp, and Cymatogaster aggregata, a small bay fish, were collected with a push net in shallow water eelgrass in Yaquina Bay. The prey were weighed and counted before they were added to the system. The prey were counted daily and the predators were weighed at the end of the experiment.

EXPERIMENT II: GROWTH OF CYMATOGASTER AGGREGATA

Approximately 400 shiner perch were collected in the first week of August in shallow eelgrass near the Marine Science Center. Each day's collection of fish was placed in the large tanks. At the end of the week all the fish were weighed in groups of ten in beakers of water on a Mettler top pan balance. Equal numbers of fish were placed in each tank.

The fish were fed Oregon pellets three or four times each day. Oregon pellets are a commercial fish food developed by the Oregon Fish Commission and O.S.U. for feeding salmon in hatcheries. The pellets are produced by Bioproducts, Inc. of Warrenton, Oregon. (Formula specifications available from the company and Crawford and Law, 1972). The fish were started on 1/16 inch pellets and then changed to 3/32 inch pellets. Specimens in Tank A received as many pellets as they could eat. Feeding was stopped when pellets hit the bottom of the tank without being consumed. Tank B received 1/2 the weight of food per fish placed in Tank A.

Ten fish were removed every six days. Live wet weights were recorded to the nearest 0.1 gm. Some fish were sacrificed and dried in a vacuum desicator overnight at 100°C. Fork lengths were recorded in millimeters. Dried weights and precise wet weights were obtained in milligrams on a Mettlet balance. Dried fish were then ashed in a muffle oven overnight at 500°C and then ashed weights determined.

Some of the fish removed after live weight measurements were placed in the small tank (A-1) and feces were collected daily to establish a relationship between food consumption and feces production. These fish were on the same feeding schedule as Tank A (as much food as they could eat three or four times a day). Some of the live weight fish were returned to their original tank.

Stomach contents were recorded for some of the freshly caught fish.

RESULTS

EXPERIMENT I: PREDATOR-PREY RELATIONS

Sculpins were maintained for two weeks in the presence of prey specimens in the seawater tanks. Typically they congregated on the bottom of the tanks in the vicinity of the out flow pipes, movements were rare, and they were never observed feeding on the prey. Counts of the food organisms (Hemisgrapsus nudus, Crago nigricauda, and Cymatogaster aggregata) remainded constant. Individual sculpins which had been weighed and tagged lost approximately 10 percent of their body weight after two weeks, at which time the experiment was terminated.

The stomach contents of Enophrys bison about 10 cm long indicated that they fed mostly on green algae. The small amount of animal material found included small crabs, ghost shrimp and a polychaete worm.

EXPERIMENT II: GROWTH OF CYMATOGASTER AGGREGATA

The shiner perch was selected for this experiment because it acclimated well to laboratory conditions, readily accepted Oregon pellets, and had low mortality after the first week following capture. Their small size meant that a large population could be maintained in the laboratory. The use of Oregon pellets as a food source gave the further advantage that regulated amounts of pollutants could be added to the food source. Monitoring of intake, mode and percent of uptake could be much more definitive.

Initial mortality after collecting and weighing fish was very high. The number of fish in Tank A fell from 200 to 107 and in Tank B from 191 to 63 in the first week. Subsequent mortality in the next three weeks was six and eight, respectively. This initial stress situation selected for those fish which could withstand the stress of capture and weighing as there was no more 10 percent mortality among the samples of ten fish removed each week from the tank for weighing and then returned.

The stomach analysis revealed that the fish are probably primary carnivores. Stomachs were full of harpacticoid copepods, mostly nauplii. Observation of feeding behavior and the place of capture indicates that they find their prey on the eelgrass. At the time of capture, shiner perch made up 50 percent by numbers of the small fish captured with a push net.

Figure 2 gives the mean wet weight of fish throughout the experiment. Feeding levels of 0.725 g (wet weight) of Oregon pellets per fish during the six day interval produced significant weight gain. Feeding rates of 0.36 g seemed to be a maintenance level as there was no significant gain or loss. The lack of growth for the feeding level of 1.25 g suggests a leveling off after an initial period of rapid growth, however, this may not have been a representative sample.

The very rapid increase in growth rate with increase in consumption rate is shown in Figure 3. Graphs of this relationship normally show an increase in growth with consumption followed by a horizontal asymptote where increase in consumption does not cause an increase in growth (Davis and Warren, 1968). The relationship indicated in Figure 3 may be a short-term phenomenon characteristic of very young fish.

The relationship of dry weight (y) to wet weight (x), $y=0.22x$, is illustrated in Figure 4. Figure 5 shows the relationship of dry weight (mg) to fork length (mm); $\log y = 3.50 \log x - 3.22$. For 3/16 inch Oregon pellets dry weight is 70 percent of wet weight.

The relationships of wet to dry weight given above were used to calculate the data in Figure 6. Direct caloric measurements were not made, but they may be determined indirectly for food and fish by using the average value of 5.65 kcal./gm. (dry weight) (Davis and Warren, 1968). A change of 15 mg. per day is significant at the 90 percent confidence level.

The mean fork length of speciments in Tank A increased 5.8 mm (13.2 percent of initial length) during the experiment (Fig. 7). There is no significant difference in length between fish on either feeding rate.

Eleven fish were kept at the same feeding level as Tank A in the small tank. A daily collection of feces showed that dry weight of feces is 10 percent of the dry weight of Oregon pellet food consumed.

Maximum levels of six heavy metals were determined and are listed in Figure 8. These can be used as a baseline for further study on the uptake and effects of heavy metals. All the figures preceded by a less than sign indicate that the sample tested was not large enough to test below that upper limit. Levels may actually be far below these maxima.

Observations of the fish indicated that it took about one week for most of the fish to be conditioned to feeding; that is, come to the surface to await food when a hand was placed over the tank. For the first two weeks of the experiment fish were fed 1/16 inch Oregon pellets. Because there is much more dust with this size pellet which is not eaten by the fish a change was made to 3/32 inch pellets as soon as most of the fish seemed large enough to ingest them. When a pellet was taken, it was chewed and then swallowed. The particles remaining in the mouth were spit out. It was impossible to quantify what percentage of the food this represented and for now it will have to be lumped with respiration as the amount of food placed in the tank less feces recovered and growth recorded (dry weights).

DISCUSSION

It was found that buffalo sculpins did not adapt to the experimental conditions. They are not recommended for laboratory growth experiments.

The shiner perch are viviparous, our experimental fish were probably born in June or July. Measurements by Wilson and Milleman (1969) in Yaquina Bay indicate that mean weight at birth is 0.494 ± 0.154 gm and mean total length is 36.2 ± 5.5 mm. At the beginning of the experiment on August 4, the mean weight was 2.000 ± 0.7 7 gm and the mean total length was 52.8 ± 9.5 mm.

Shiner perch are distributed along the Pacific coast from Southern California to Alaska (Wilson and Milleman, 1969). They inhabit bays and estuaries in large numbers during the summer months. This makes them an ideal fish for studying the effects of pollutants in the coastal marine environment.

The work to date indicates that Cymatogaster aggregata can be successfully maintained in the laboratory and that growth rates can be fairly well predicted for this stage in the life cycle. The two populations gave consistent and similar results.

The fish did not show any tendency to school separately by age and sex (Wiebe, 1968) but this may have been a factor of tank size and young age.

A cinder block was placed in the small rectangular tank (1-A) and the fish quickly adopted it as a hiding place, retreating when frightened. The fish in the large tanks did not have hiding placed although they would congregate near inflow and outflow pipes. Their behavior was not as timid as the fish in the small tank.

Experiments should be carried out with small groups of fish (10 to 20 fish) in small tanks so that the growth rates of individual groups may be monitored. Several experiments may than be carried on simultaneously.

In the future, a large stock population should be maintained in the large tanks. The less adaptable fish could be weeded out before being placed in an experimental situation.

At the end of the experiment all fish could be sacrified for weight and length measurements and any applicable bio-assays.

Smaller tanks might also break down pecking orders especially notable in the low feeding rate tanks where a few fish got larger while the majority did not gain weight. Smaller groups of experimental fish would also allow more opportunity to match sizes of fish and keep out the extreme outliers.

It may be possible to establish a breeding population in the large tanks. It will probably be necessary to establish hiding places.

To date there have been no problems with disease or water quality. As the water is drawn from the bay it is not expected that the salinity or temperature extremes will harm these fish.

This work has found Cymatogaster suitable for experimental work because growth rates are consistent with consumption rates for different groups of fish.

CONCLUSIONS

1. Enophrys bison can not be successfully cultured in a predator-prey system.

2. There was a 50 percent mortality when one month old Cymatogaster aggregata were introduced to the laboratory. After this initial stress, mortality dropped to about 1 percent per week.

3. A feeding schedule of 0.12 gm (wet weight) of Oregon pellets per fish per day will cause a significant weight gain in one week among fish one to two months old.

4. A feeding schedule of half this amount to a comparable group of fish caused no weight gain. There was no significant difference in fork length for either group.

5. Dry weight of feces was 10 percent of dry weight of food under feeding conditions of 0.12 gm (wet weight) of Oregon pellets per fish per day.

6. The relationship of wet weight (x) to dry weight (y) for fish was $y = 0.22x$. For Oregon pellets the comparable relationship was $y = 0.708x$.

7. Growth rate increased rapidly with consumption rate. For the age group tested, there was a fairly steady increase of 10 mg per gram of body weight each day for each 20 mg increase in consumption rate. This relationship apparently peaked at a consumption rate of 240 mg of Oregon pellets per gram of fish body weight per day. This sharp increase in growth rate with consumption rate was probably a factor of the very young age of the fish.

8. The relationship of dry weight (y, in mg) to fork length (x, in mm) was $\log y = -3.22 + 3.50 \log x$.

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This study would not have been possible without the continued support of WICHE, the members of the National Coastal Research Program in Newport, the many scientists and students attached to the Marine Science Center, the zooplankton group of the School of Oceanography of Oregon State University and my husband, Roger.

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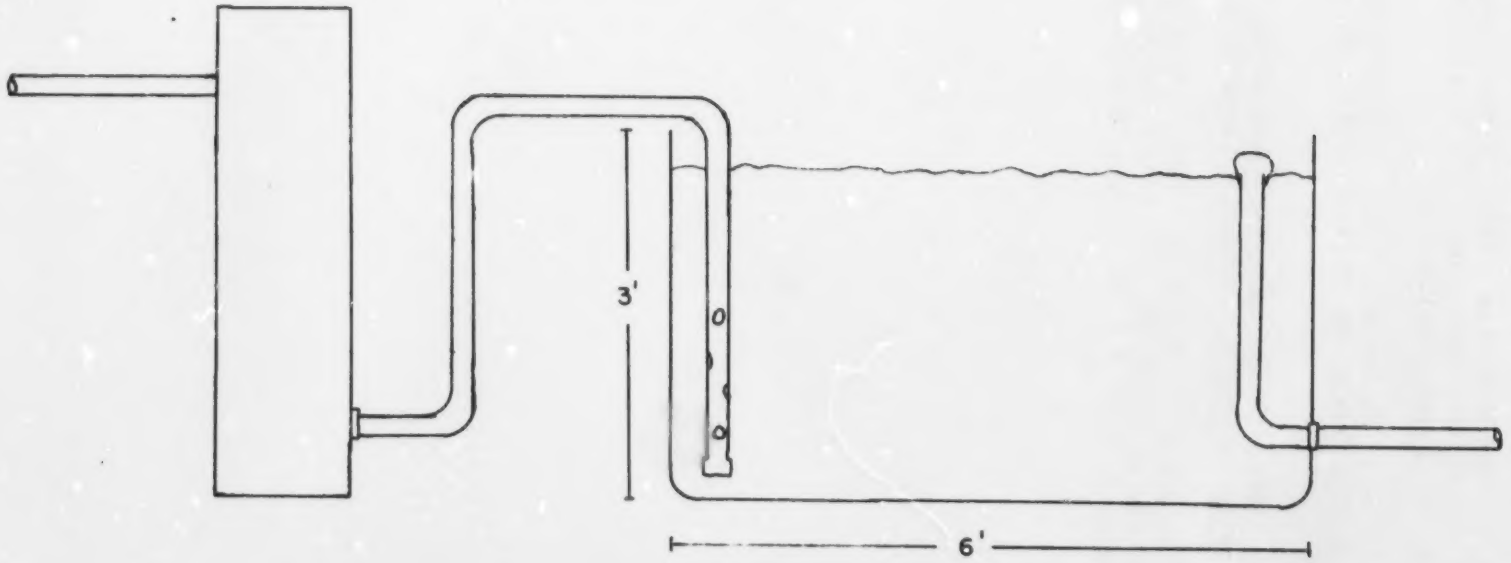


Figure 1. A diagram of a filter and large cirular tank. Tank capacity = 575 gallons. Flow rate = 2-3 gal/min.

Figure 2. A graph of live weight of 10 fish at six day intervals. Tank A is designated by a solid line, Tank B by a broken line. The vertical lines at Aug. 4 indicate the 90 percent confidence limits for the 200 and 191 fish, respectively, placed in each tank. The numbers above the lines indicate the wet weight in grams of Oregon pellets fed per fish during the six day interval.

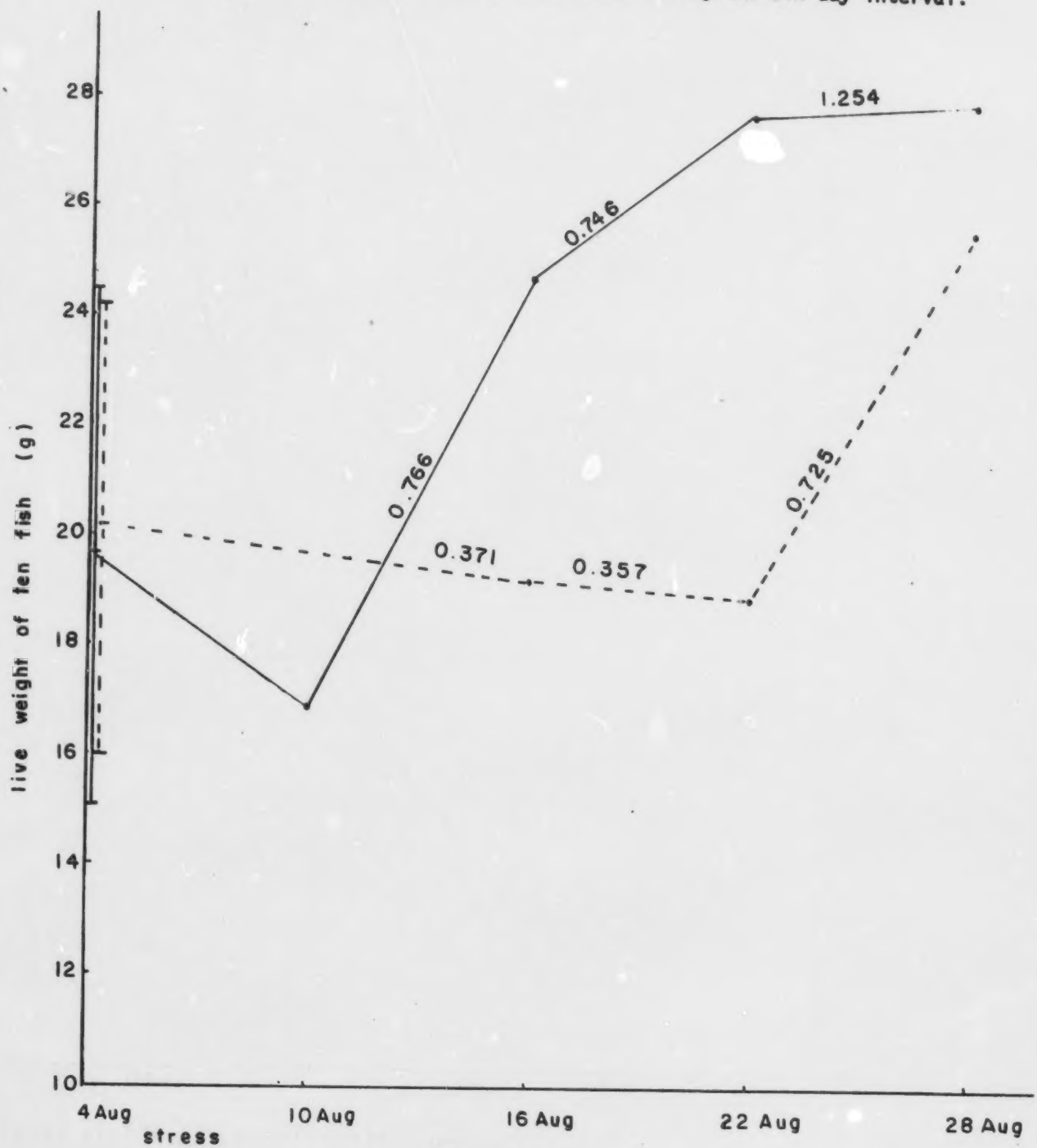


Figure 3. A graph of consumption rate versus growth rate. Rates are determined by milligrams of food consumed or weight gained per gram of fish per day. All measurements are dry weights.

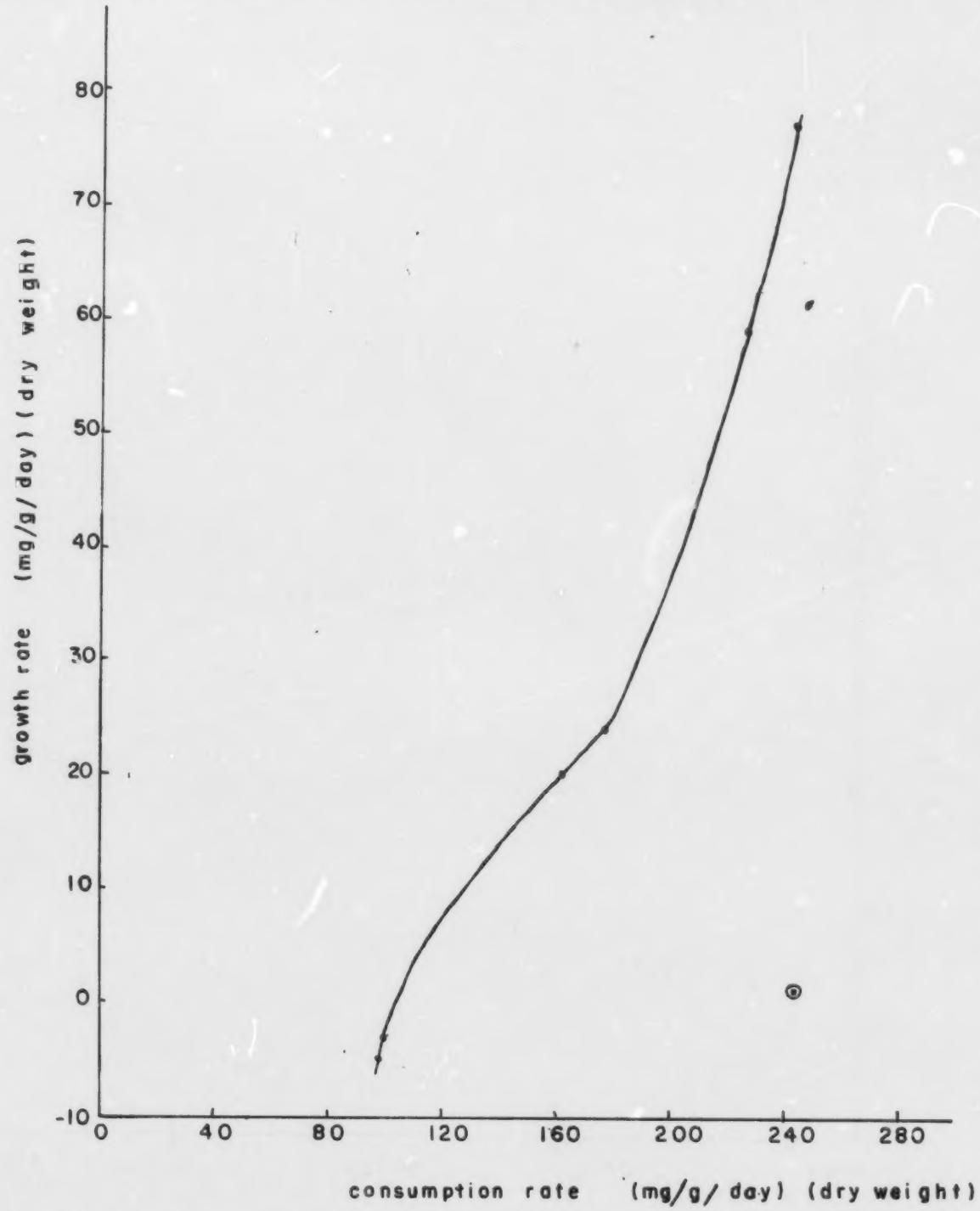


Figure 4. A graph of wet weight versus dry weight for Cymatogaster aggregata two to three months old.

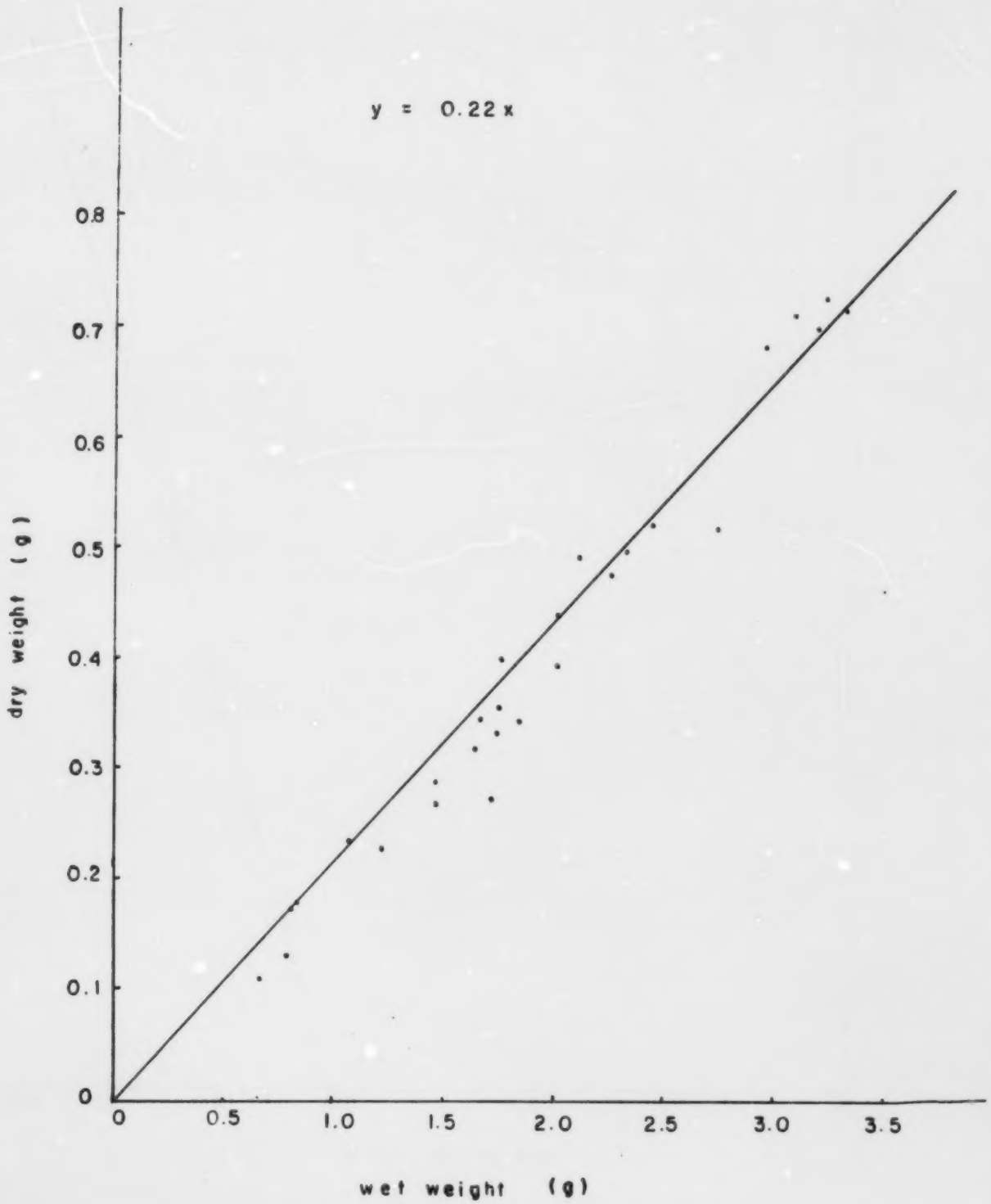
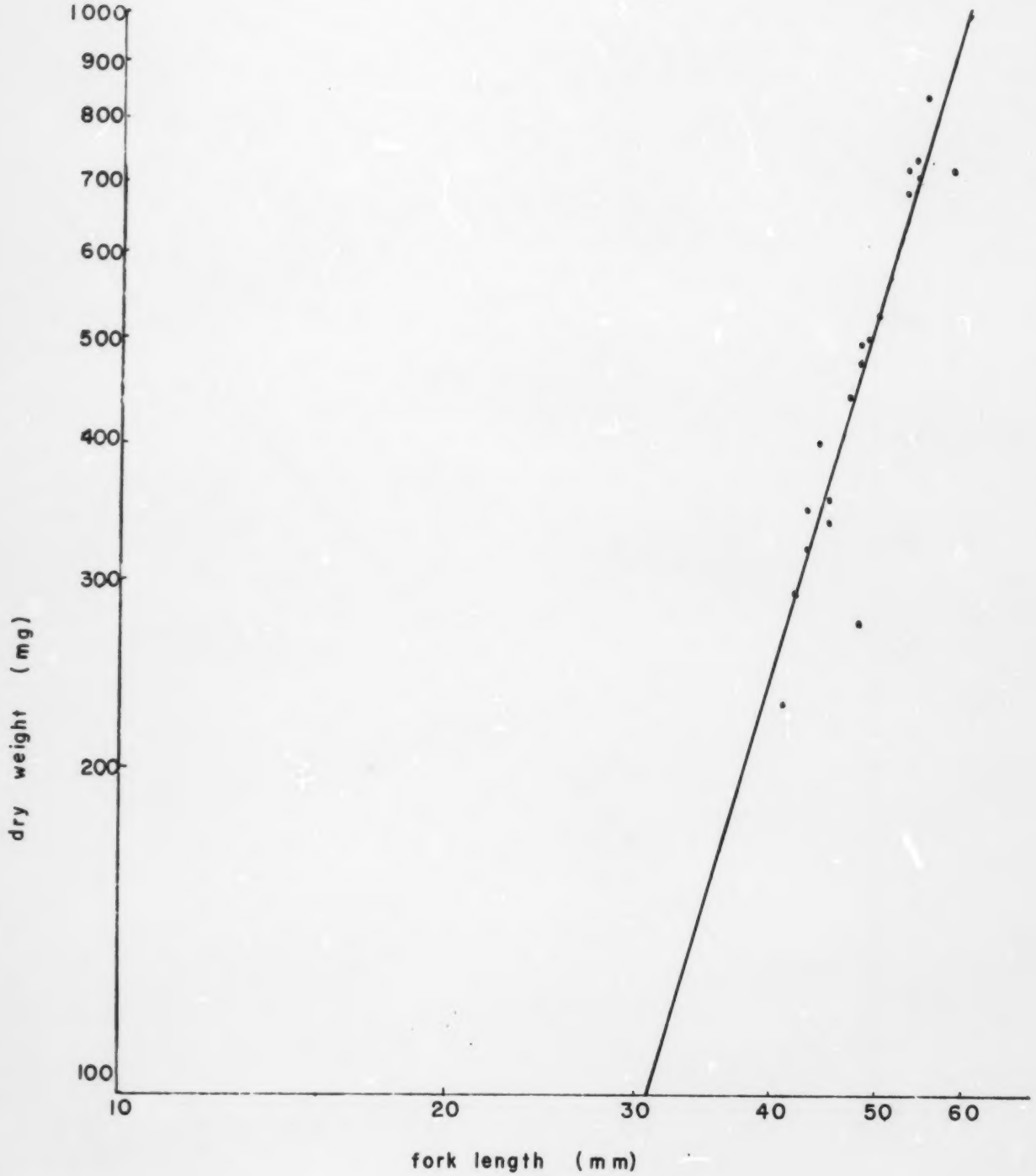


Figure 5. A log graph of fork length in mm (x) versus dry weight in mg (y) for Cymatogaster aggregata two to three months old. Log y = 3.50 log x - 3.221. Correlation coefficient, R = 0.92.



Dry weight Values of Food and Fish

Tank	Dates	Population Size	Sample Size	mg. of food fed/fish/day	mg. of wt. gained/fish/day	Avg. wt. of fish at end of period mg	Comments
A	Aug. 4	200	200			436 ± 104	90% CI
B	Aug. 4	191	191			444 ± 90	
A	Aug. 4-10	107	10	77	-11	371	stress
B	Aug. 4-10	63	10	62			
A	Aug. 10-16	92	10	90	29	543	
B	Aug. 10-16	58	10	44	- 2	422	
A	Aug. 16-22	82	10	88	11	609	
B	Aug. 16-22	58	10	42	- 1	416	
A	Aug. 22-28	71	10	148	1	614	
B	Aug. 22-28	56	10	86	25	563	

Figure 6. Dry weight of food consumed and weight gained for Cymatogaster aggregata experiments. Dry weight (y) relationship to wet weight (x) for Oregon pellets : $y = 0.708x$; and for fish $y = 0.22x$.

Mean Fork Length

Tank	Dates	Population Size	Sample Size	Mean Fork Length (mm)
A	Aug. 4	200	6	43.8
B	Aug. 4	191		
A	Aug. 10	107	-	-
B	Aug. 10	63	-	-
A	Aug. 16	92	3	46.3
B	Aug. 16	58	-	-
A	Aug. 22	82	9	48.0
B	Aug. 22	58	-	-
A	Aug. 28	71	5	49.6
B	Aug. 28	56	5	48.2

Figure 7. Mean length of Cymatogaster aggregata during experiments.

	Sample		
Metal	Whole Fish ppm	Oregon Pellets ppm	Feces ppm
Cr	<1	<1	-
Cu	<0.5	<0.5	-
Hg	0.8*	0.2	0.5
Ni	<1.5	<1.5	-
Pb	<4	<4	-
Zn	17.3	51	-

*Muscle Tissue only

Figure 8. Parts per million of heavy metals found in one to two month old Cymatogaster aggregata removed from Yaquina Bay, Oregon pellets, and feces of Cymatogaster aggregata fed on Oregon pellets. Values preceded by a "less than" sign are the minimum detection limits and no detectable amount was present.

This report was completed by the following intern:

Name: Anne H. Myers

Address: 4230 N.W. Delta, #4
Corvallis, Oregon 97330

Immediately prior to this internship, the intern was a student at:

College: Oregon State University

Major Field: Bio. Ocean.

Year in School: M.S. June 1974

This intern report was read and accepted by a staff member at:

Agency: Environmental Protection Agency
Pacific Northwest Environmental Research Lab

Address: 200 S.W. 35th Street
Corvallis, Oregon 97365

If you have further comments about this intern report, please write or phone:

Bob Hullinghorst, Director
Resources Development Internship Program
Western Interstate Commission for Higher Education
P.O. Drawer "P"
Boulder, Colorado 80302

Phone: (303) 449-3333

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THE RESOURCES DEVELOPMENT INTERNSHIP PROGRAM

The preceding report was completed by a WICHE intern during the summer of 1973 This intern's project was part of the Resources Development Internship Program administered by the Western Interstate Commission for Higher Education (WICHE).

The purpose of the internship program is to bring organizations involved in community and economic development, environmental problems and the humanities together with institutions of higher education and their students in the West for the benefit of all.

For these organizations, the intern program provides the problem-solving talents of student manpower while making the resources of universities and colleges more available. For institutions of higher education, the program provides relevant field education for their students while building their capacity for problem-solving.

WICHE is an organization in the West uniquely suited for sponsoring such a program. It is an interstate agency formed by the thirteen western states for the specific purpose of relating the resources of higher education to the needs of western citizens. WICHE has been concerned with a broad range of community needs in the West for some time, insofar as they bear directly on the well-being of western peoples and the future of higher education in the West. WICHE feels that the internship program is one method for meeting its obligations within the thirteen western states. In its efforts to achieve these objectives, WICHE appreciates having received the generous support and assistance of the Economic Development Administration, the Jessie Smith Noyes Foundation, the National Endowment for the Humanities, the National Science Foundation, and of innumerable local leaders and community organizations, including the agency that sponsored this intern project.

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For further information, write Bob Hullinghorst, Director, Resources Development Internship Program, WICHE, Drawer "P", Boulder, Colorado, 80302, (303) 443-6144.